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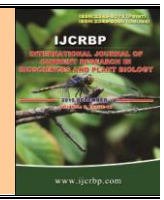

Original Research Article

Nuclear Techniques for Treating Sewage Water

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Abstract

Water shortage and high demands for fresh water as a result of population growth made the situation very demanding to find other sources of water. North Africa especially Libya has severe fresh water shortage; this made it very necessary to look for suitable substitutes. The treatment of sewage water and reusing it for agricultural purposes can save large quantities of fresh water for future generations. Samples of sewage water from Alhadba Alkhadra sewage treatment plant were brought in sterilized glass bottles and tested chemically and biologically. Samples were irradiated by gamma irradiation from a ^{60}Co source at different doses ranged between 0.5 and 3 kGy at a dose rate 8.3 gray per minute, one sample was left un-irradiated for comparison purposes. Conventional microbiological techniques were used to assess microbial gamma radiation inactivation. All bacteria that were under investigation were eliminated which will make the treated water safe for reuse. The radiation treatment had no effect on pH and E.C readings whereas BOD and COD values were reduced.

Keywords

Escherichia coli
Gamma irradiation
Salmonella
Sewage water
Shigella

Introduction

Libya is located in an arid and semi arid zone with limited ground water resources; it has an intense Mediterranean climate with low precipitation rates and high rates of evaporation. Due to the shortage of fresh water reusing sewage water for agricultural purposes is seriously considered; in this paper the viability of nuclear techniques as a method of treatment was studied and to some extent enhancing this treated water for useful purposes. Wastewater should be properly treated before using it for irrigation purposes. The removal of pathogenic organisms is a very important measurement of treated sewage water for the purpose of reuse, whereas removal of suspended solids and reduction of biological oxygen demand are usually required for pollution control (Long and Cudney, 2012). Several methods have been used including anaerobic digestion, composting, and thermal disinfection for making the sludge biologically and chemically safe. But these conventional methods seem to be insufficient to eliminate the pathogens from wastewater (El-Fouly et al., 1996). Technically, ionizing radiation results in radiolysis of water and produces hydrated electrons, hydrogen, and hydroxyl free radicals (Caër, 2011). Strong chemical reactivity of these components results in inactivation of microorganisms and decomposition of pollutants.

One of the main reasons for exploring this technology was to provide an alternative method for disinfection. There are two reasons that are mentioned for attempting to find a substitute for chlorination; its toxicological effects to aquatic organisms and the formation of by-products when chlorine combines with and inorganic ammonia, forming chloramines and organic material in the waste, forming organo-halogen compounds (Sabbagh et al. 2014). Ionizing radiation has a strong direct effect on organic materials in waste water because of the strong energy of gamma radiation which changes the characteristics of pollutants (Al-Ani and Al-Khalidy, 2006).

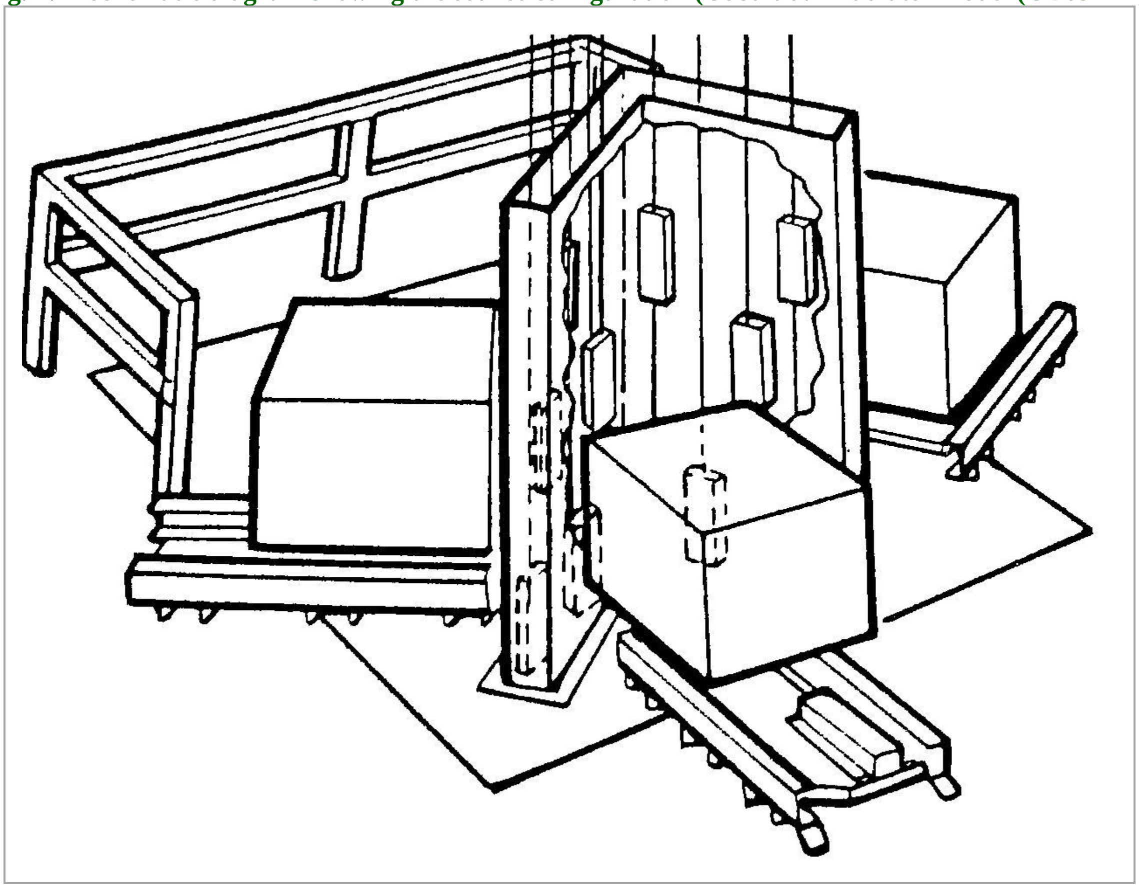
The objectives of this study are to evaluate the applicability of ionizing radiation technology for reducing the total bacterial count and removing pathogenic organisms and decreasing COD and BOD values in sewage water.

Materials and methods

Samples collection and irradiation

Several samples of waste water were obtained from Al-Hadba Al-khadra, municipal wastewater treatment plant. This plant is located about 5 km from the city center of Tripoli and about 80% of the city population is connected to the network. Samples were placed in sterilized glass bottles and transported to the laboratory in ice boxes and analyzed microbiologically and chemically by adopting standard procedures (APHA, 1995 and 2005). Samples were irradiated using Cobalt 60 irradiator model (GB651PT), Nordion International Inc. (Fig. 1), with a dose rate of 8.3 Gy/min as determined using Frecke dosimeter. Samples were placed in 100 ml of sterile poly propylene containers and irradiated using 0.5, 1.0, 1.5, 2.0, 2.5 and 3.0 kGy.

Fig. 1: A schematic diagram showing the source configuration (Cobalt 60 irradiator model (GB651PT).



Microbiological examination

Microbiological examination of wastewater sample is to determine sanitary quality. Plate count method was used to enumerate the microbial count. Each sample (25 g) was added to 250ml of 0.1% (w/v) peptone water. One ml of each sample was serially diluted (10^{-1} to 10^{-6}) with 9.0 ml of 0.1% peptone water. Then, 0.1 ml of diluent was spread-plated onto Plant Count Agar (Oxoid). All the plates were incubated at 37^{o}C for 24-48 h (ISO, 2003). The colony count was calculated by multiplying the average number of colonies per countable plates by the reciprocal of the dilution. Plate count number is represented by colony-forming units (CFU). All samples were examined for *Salmonella spp.*, *Shigella spp.* and *E. coli* Suspected colonies from MacConkey Agar (Oxoid), Salmonella-Shigella Agar (Oxoid) and XLD-agar (Xylose Lysine Deoxycolate agar) plates (Oxoid) were isolated and identified biochemically using standard microbiological procedures (Forster-Carneiro and Perez, 2010) and API 20E (bioMerieux, France).

Chemical measurements

The chemical measurement parameters taken for this study were: biochemical oxygen demand (BOD5), chemical oxygen demand (COD) electrical conductivity (EC) and pH.

Determination of BOD and COD

The Biological oxygen demand (BOD) test was used to determine the relative oxygen requirements for wastewater, effluent and polluted water. 500 ml was taken from both samples (raw and treated), they were first filtered and their pH was adjusted between 6.5 and 7.0, using sulphuric acid. Each 500 ml beaker was divided between three BOD bottles (157 ml in each bottle). Bottles were placed in the cabinet at the same time and incubated at 20^{o}C for five days. Results were read directly from the BOD sensor. Chemical Oxygen Demand COD: It is the measurement the oxygen equivalent of the organic matter content of the samples that was susceptible to oxidation by strong oxidant.

Determination of pH and E.C

pH and E.C were measured using pH meter (Model-720 A) and E.C (Cole Parmer).

Results and discussion

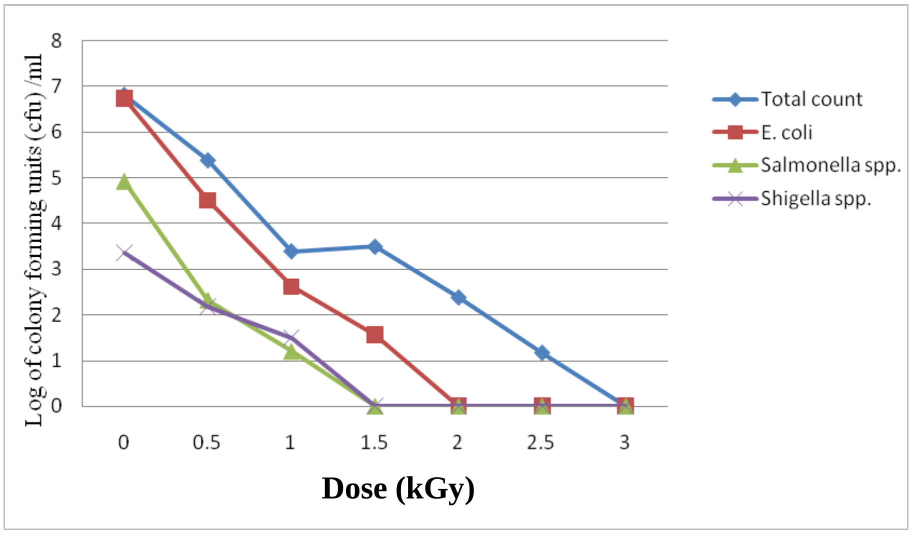
Effect of gamma radiation on microorganisms

Several samples were obtained from Al-Hadba wastewater treatment plant to examine the effect of various radiation doses on microorganism. Ionizing radiation of a radioactive sources or accelerators causes alteration in cell membranes and then destroy bacteria, fungi, viruses, etc. as well as breaks chemical chains in some toxic substances like pesticides, herbicides, PCPs which are included in the sludge contents (Sinha et al, 2009). Fig. 2 summarizes the data for the total bacteria, *E. coli*, *Salmonella spp.* and *Shigella spp*., for samples collected from the final stage of treatment plant at various radiation doses. As a result of increased exposure of gamma radiation, the number of bacterial population decreased according to the curves shown in (Fig. 2). It can be clearly seen that a dose of 2 kGy is need to eliminate *E. coli* bacteria whereas only a dose of 1.5 kGy is needed to clear off *Salmonella spp.* and *Shigella spp*. Each microorganism in the present study showed different lethal dose that causes sterilization of the samples. This indicates that the microorganisms have different response to radiation. All tested microorganisms were virtually eliminated at a dose of 3 kGy obtained from sewage water.

Preez et al. (2003) reported that was difficult to detect *Shigella spp.* in sewage water samples. Our finding experiments suggest that *Shigella spp.* can survive in wastewater. The recovery of enteric pathogens from waste water is often complicated by multiple factors including; transport stress, intermittent shedding of pathogens in the waste matter. This would decrease the probability that numbers of *Salmonella* or *Shigella* in relation to other enteric flora would be present in the sewage water. These factors necessitate the use of selective/differential media. Xylose lysine deoxycholate agar was especially designed to allow the growth of *Shigella*, and *Salmonella* species and biochemical tests were done by using API 20E test kit. Yeast and fungi in sewage water were more sensitive to ionizing radiation than bacteria; they were eliminated at a 0.5 kGy dose (results not shown).

All forms of ionizing radiation exert their effect on cells by displacing electrons from molecules and atoms with which they collide, causing ionization and inducing a cascade of events that may alter the cell transiently or permanently. The most important target molecule in living cells is DNA. Ionizing radiation may directly damage DNA, but more often the DNA is indirectly damaged by inducing the formation of free radicals, particularly those that are formed from the radiolysis of water (Bajinskis, 2012). The results showed that gamma radiation was very effective in eliminating pathogenic bacteria in treated sewage water, due to of the strong activity of radiation energy that changes the characteristics of pollutants in the wastewater.

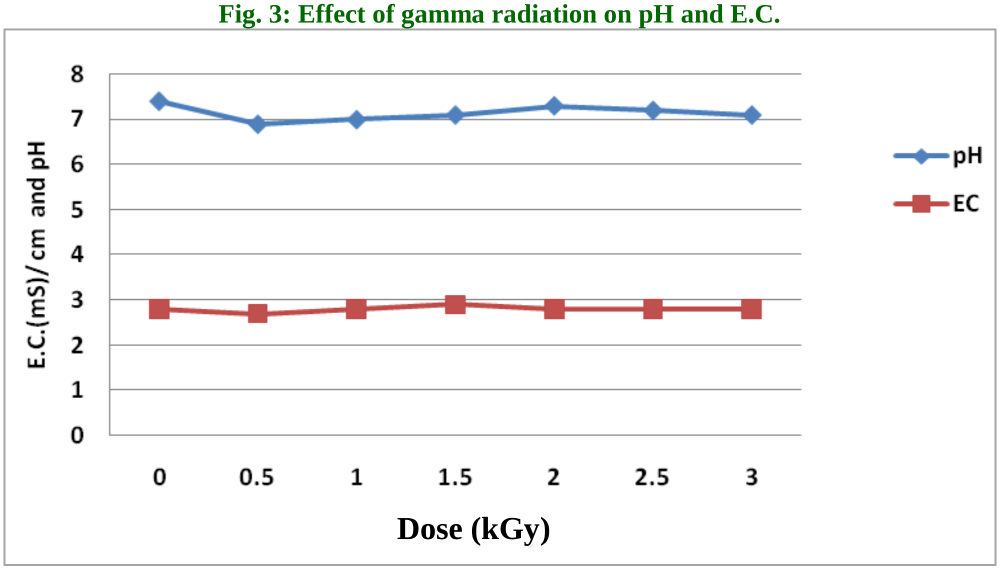
Fig. 2: Effect of gamma radiation on total bacteria count, *Escherichia coli*, *Salmonella spp*. and *Shigella spp.* of sewage water.



Effect of gamma radiation on pH and E.C.

Measuring the pH for the control and irradiated sewage samples found to be in the range between 6.9 and 7.3 (Fig. 3). However, there was no effect of gamma irradiation on pH. This indicates that the medium is neutral, therefore most probably due to domestic input of wastewater. Furthermore, results showed that EC values remained stable for all the radiation doses and do not degrade the inorganic materials consequently the salinity value does not change with the increase in radiation dose.

Fig. 3: Effect of gamma radiation on pH and E.C.



Effect of gamma radiation on BOD and COD

The effect of gamma radiation on BOD and COD values were measured in the irradiated and non irradiated wastewater samples in the last stage of treatment of the sewage water plant. As shown in Table 1, the COD value at 3kGy was (183 mg/l), is lower that the non-irradiated sample (459 mg/l). The chemical oxygen demand is the measure of oxygen equivalent of the organic matter content of a sample that is susceptible to oxidation by a strong oxidant (Clesceri et al., 1998). The COD value decrease at different doses might be explained by the radiation-induced effect on the degradation of molecules that leads to the increase of the number of low-molecular weight substrates.

There is a decrease of the BOD values after irradiation. The reduction in organic matter contents (BOD) was due to gamma irradiation with different doses (0-3.0 kGy). It is clear that the percent reduction decrease with increasing gamma dose. The reduction of BOD is related to the biochemical degradation of organic material. High BOD values in sewage water, weakens the process of germination and delays the early growth of many crops (Nashikar, 1994). The reduction in BOD at 3 kGy was 59% (Table 1). Nevertheless, Basfar and Rehim (2002) found a reduction of BOD 24% at 4 kGy. This decrease probably caused by the destruction of bacteria responsible for oxygen consumption.

Table 1. Effect of gamma radiation on BOD and COD.

Dose	BOD mg/l	Reduction %	Dose	COD mg/l	Reduction %
Non irradiated sample	255	-	Non irradiated sample	459	-
0.5 kGy	210	17	0.5 kGy	380	17
1.0 kGy	185	27	1.0 kGy	332	28
1.5 kGy	160	37	1.5 kGy	280	39
2.0 kGy	145	43	2.0 kGy	258	44
2.5 kGy	137	46	2.5 kGy	240	48
3.0 kGy	105	59	3.0 kGy	183	60

Conclusion

Irradiation of waste water is a very important process to eliminate all types of microorganisms and to improve its characteristics, as long as the radiation parameters are correctly suited to the application. This treatment will have a very good ecological, economic and could lead to additional opportunities for the reuse of this valuable resource, where it can be used safely for irrigation purposes because of its nutrient value. Furthermore, this study accentuates implementation for developing countries to combat against water shortage.

Acknowledgement

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